PUMP PLUG

The present invention relates to a pump plug for use in flowline operations, such as for displacing well tools via a flowline to a well, for well swabbing operations, for displacing well tools through a production tubing in a well, or for displacing a device for expanding a well tubular, such as an expandable slotted tube or an expandable solid tube. In general, the pump plug is used to displace a tool through a flowline having a flow passage, wherein the pump plug is pumped through the flowline. Examples of such flowlines are flowlines, surface pipe, well tubulars and so on.

An example of such a pump plug is described in British patent specification No. 1 321 152. The known pump plug had been developed to provide a pump plug that could pass through a flowline having abrupt changes in diameter of the flow passage. To this end the known pump plug comprises a cylindrical body, a tubing of elastomeric material surrounding the body, and rigid fittings attached to the outer surface of the tubing, wherein the rigid fittings comprise a first series of segmental fittings spaced-apart around the centre of the body at right angles to its longitudinal axis and a second series of fitting, the fittings of the second series being elongate and each having one end in contact with a fitting of the first series. Furthermore an elongated fitting is situated adjacent a space between two fittings of the first series, and between every two elongated fittings adjacent a space there is arranged at least one other elongated fitting.

A disadvantage of the known pump plug is that its manufacture is complicated, because of the two series of

fittings that have to be made separately and assembled so as to form a seal.

It is an object of the present invention to provide a simpler design of a pump plug.

To this end the pump plug for flowline operations according to the present invention comprises a resilient body and a flexible cage having a wear-resistant outer surface arranged around the resilient body, wherein the flexible cage comprises a tube having a first end and a second end, which tube is provided with a repeating pattern of slits closed at at least one end.

The invention will now be described by way of example in more detail with reference to the accompanying drawings, wherein

Figure 1 shows schematically a longitudinal section of the pump plug according to the present invention;

Figure 2 shows schematically a flattened view of part of the pump plug according to Figure 1;

Figure 3 shows schematically a longitudinal section of an alternative embodiment of the present invention; and

Figure 4 shows schematically a flattened view of part of the pump plug according to Figure 3.

Reference is now made to Figure 1, showing a first embodiment of the pump plug 1 for flowline operations according to the present invention. The pump plug 1 comprises a resilient cylindrical body 2 and a flexible cage 3 having a wear-resistant outer surface 4 arranged around the resilient cylindrical body 2.

We now refer to Figure 2 to discuss the flexible cage 3 in more detail. The flexible cage 3 comprises a tube 5 having a first end 6 and a second end 7. The tube 5 is provided with a number of axial slits 9 and 10 closed at at least one end. For the sake of simplicity the resilient body is not shown in Figure 2.

In the embodiment of the invention shown in Figures 1 and 2, the slits 9 and 10 form a repeating pattern of two slits, a first slit 9 that is closed at the first end 6 of the tube 5 and open at the second end 7, and a second slit 10 that is closed at the second end 7 of the tube 5 and open at the first end 6. Adjacent slits define elongated bars 15 that are joined at their ends by connection elements 16 that serve as a dam.

The repeating pattern of the slits 9 and 10 is repeated in circumferential direction, so that the pattern is symmetrical about an axis 17 that is parallel to the central longitudinal axis 18 of the pump plug 1.

When the pump plug 1 is inserted in a flowline (not shown), the flexible cage 3 serves as a sliding seal for the pump plug 1 because the connection elements 16 prevent fluids from flowing along the resilient cylindrical body 2. Since the outer surface 4 of the flexible cage 3 is of wear-resistant material, the flexible cage 3 forms a protective outer layer on the resilient cylindrical body 2. The resilient cylindrical body 2 forms a static seal.

During normal operations, the pump plug of the present invention is used for displacing a well tool through a flowline (not shown). The dimensions of the pump plug should be so selected that the outer surface 4 of the flexible cage 3 is in contact with the inner surface of the flowline, in such a way that a seal is formed. Assume that the pump plug 1 is displaced through the flowline with its first end 6 in the direction of displacement, and that it encounters a part with a reduced flow passage. When encountering a reduced flow passage, the following will happen. At the front end 6 of the pump plug 1 the bars 15 will be forced to rotate in the direction of arrow 19, so that the ends of the bars 15 at the front end 6 will displace into the

resilient cylindrical body 2. This will enable the pump plug to pass along the part with the reduced flow passage. The rotation can go on until the gaps of the slits 10 close. Thus dimensions of the flexible cage 3 have to be selected such that the pump plug can pass along the smallest flow passage that is expected in the flowline through which the pump plug is pumped.

Reference is now made to Figures 3 and 4 showing an alternative embodiment of the present invention. The pump plug 1a comprises a resilient cylindrical body 2a, 2b and a flexible cage 3a having a wear-resistant outer surface 4a arranged around the resilient cylindrical body 2a, 2b, wherein the flexible cage 3a comprises a tube 5a having a first end 6 and a second end 7, which tube 5a is provided with a number of slits 41, 42 and 43 that are closed at at least one end. For the sake of simplicity the resilient body is not shown in Figure 4.

The resilient cylindrical body 2a, 2b comprises a rigid cylindrical core 2a and a mantle 2b of resilient material fixed on the outer surface of the rigid core 2a. The use of a rigid core is particularly suitable for operations in which a large pressure difference is applied over the pump plug.

The slits 41, 42 and 43 form a repeating pattern of a first slit 41 a second 42 and a third slit 43. The first slit 41 is closed at both ends 6 and 7 of the tube 5a. The third slit 43 is aligned with the second slit 42. The second slit 42 and the third slit 43 are open at opposite ends of the tube 5a and closed in the middle of the tube 5a by connection elements 45. Between the slits 41 and 42 and 43 bars 15a are defined, wherein the bars 15a at either side of a first slit 41 are joined at their ends by connection elements 16a. The connection elements 45 and 16a serve as dams. When the pump plug 1a is inserted in a flowline (not shown), the flexible

cage 3a serves as a sliding seal. The resilient cylindrical body 2a forms a static seal.

In an alternative embodiment, the connection elements 16a at the end 7 of the pump plug can be omitted.

The repeating pattern of the slits 41, 42 and 43 is repeated in circumferential direction, so that the pattern is symmetrical about an axis 17a that is parallel to the central longitudinal axis 18 of the pump plug 1a.

The repeating pattern of the slits 41, 42 and 43 can be construed as a repetition of the pattern shown in Figure 2 in axial direction, wherein the pattern shown in Figure 2 is mirrored about a plane perpendicular to the central longitudinal axis 18. The intersection of the plane and the plane of drawing of Figure 2 is a dot and dash line referred to with reference numeral 46.

It will be understood that the repeating pattern of the slits 41, 42 and 43 can be repeated as well in axial direction, by mirroring the pattern shown in Figure 4 about a plane perpendicular to the central longitudinal axis 18. The intersection of the plane and the plane of drawing of Figure 4 is a dot and dash line referred to with reference numeral 47. The mirrored image of slit 41 is shown in dashed lines and referred to with reference numeral 41a. In this way the repeating pattern of the slits 41, 42 and 43 is extended in axial direction with its mirror image.

The resilient cylindrical body (or the mantle) can be made of a rubber, and the slits of the tube can be filled with rubber that is vulcanised together with the rubber of the resilient body so as to form an integral part.

In order to obtain more radial resilience, the resilient cylindrical body (or the mantle) can be provided with circumferential ridges. On these ridges the

flexible cage is provided. The ridges still prevent fluid from flowing along the pump plug.

The slits shown in the embodiments of the present invention discussed with reference to Figures 1-4 extend in axial direction, however, the slits can as well be arranged under a sharp angle (less than 45°) with the central longitudinal axis of the pump plug.

The slits are so formed that the bars 15 and 15a have a rectangular cross-section. Alternatively, the cross-section is in the form of a trapezium, wherein the shorter side points in to the resilient body.

The flexible cage discussed above has a wear-resistant outer surface, this requirement is also met when the tube from which the flexible cage is made consists of wear-resistant material. Suitable tube materials are beryllium, titanium, bronze, tool steel or a ceramic.

When needed more than one pump plug can be used in series, or a resilient body can be provided with more than one flexible cage.

In order to increase the pressure exerted during normal operation of the outer surface of the flexible cage on the inner surface of a flowline, the pump plug shown in Figure 3 can be provided with a tapering space between the rigid cylindrical body 2a and the mantle 2b that is closed at one end, so that pressurized fluid can enter under the mantle 2b.

In order to push or to pull devices through the flowline, the pump plug is provided with suitable connectors, which are not discussed.

The present invention provides a simple pump plug that is easy to manufacture because the flexible cage is made of a tube provided with labyrinth slits. The pump plug according to the present invention is easy to

manufacture and does not have small parts that can be lost during operation.